Healthcare Investment and Income Inequality

Ayona Bhattacharjee[a], Jong Kook Shin[b], Chetan Subramanian[c], Shailender Swaminathan[d]

Abstract

This paper examines how the relative shares of public and private health expenditures impact income inequality. We study a two period overlapping generation's growth model in which longevity is determined by both private and public health expenditure and human capital is the engine of growth. Increased investment in health, reduces mortality, raises return to education and affects income inequality. In such a framework we show that the cross-section earnings inequality is non-decreasing in the private share of health expenditure.

We test this prediction empirically using a variable that proxies for the relative intensity of investments (private versus public) using vaccination data from the National Sample Survey Organization for 76 regions in India in the year 1986-87. We link this with region-specific expenditure inequality data for the period 1987-2012. Our empirical findings, though focused on a specific health investment (vaccines), suggest that an increase in the share of the privately provided health care results in higher inequality.

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a O.P. Jindal Global Business School, Sonipat-Narela Road, Delhi NCR. Haryana-131001, India

b Newcastle University Business School, 5 Barrack Road, Newcastle upon Tyne, NE1 4SE, U.K

c Department of Economics and Social Sciences, IIM Bangalore, Bannerghatta Road, Bangalore 560076, India

d Public Health Foundation of India, Brown University, Providence, RI, USA

1 Introduction

This paper contributes to the growing debate on whether the delivery of health care should be public or private by examining the interplay between the shares of public and private health expenditure in an economy and income inequality. Although the total spending on public and private health care has been rising in most countries, there are considerable differences in the mixture of public and private health spending both within and across countries. Our objective is to examine both theoretically and empirically the role that the mix of health expenditure between public and private plays in explaining the intergenerational transmission of income and inequality. We examine this issue in a two period overlapping generations growth model in which mortality is endogenous and human capital is the engine of growth.

There is considerable evidence that points to the fact that poor health in childhood lowers future income through its effects on schooling and labor force participation. What is less well understood is whether the share of private and public health expenditure affects income inequality. In Figure 1 we present evidence on the association between the shares of private and public health expenditure and income inequality across countries. It plots the public health expenditure (considered to be a proxy for prevalence of public health care system) as percentage of total health expenditure in 1995 against income inequality as measured by the Gini coefficient in 2010. The plot suggests that a higher share of public health expenditure is associated with lower level of income inequality in the long run. This idea is formally examined as below.

We begin by developing a theoretical model that establishes the link between the shares of public and private health expenditures and income inequality. Our paper extends the Glomm and Ravikumar (GR) (1992) model of endogenous growth, to include both public and private expenditures on health. Mortality is endogenous in our setup where the length of life of the adult depends upon a composite good we term as “health input”, a function of both public and private provision of health expenditure. Private health expenditure is incurred by the parent who has a bequest motive and invests in the health of the offspring. The government levies taxes on the income of the adults and uses tax revenues to provide "free" public health. The taxes are endogenously determined in each period through majority voting and are shown to be constant and independent of income. This allows us to abstract from political economy considerations.

Each agent’s stock of human capital depends on the parent’s stock of human capital, time spent in school, and the health input. The linkage across generations in our model therefore stems from two distinct channels. First, as mentioned earlier, the stock of human capital of the parent directly affects the human capital stock of the young. Second, the investment on the health input of the young is a function of parental human capital. The consequent impact on length of life affects the rate at which the young discount the future, thereby impacting their investment in human capital.

Next, we seek to understand the impact of the relative shares of health expenditure on income inequality. Our key takeaway is that income inequality is lower in economies which have a higher share of public health expenditure. The intuition follows from the fact that under a public regime, all agents have equal access to health care whereas under a private regime their access is dependent upon their initial income level. In particular, due to diminishing returns to human capital, low income individuals enjoy higher earnings growth than high income individuals in transition causing income inequality to shrink under the public regime. By contrast, under the private regime high income individuals invest more in health and grow faster whereas low income individuals get stuck in the vicious cycle of poor health and low income. Hence any differences in the initial level of income are exacerbated over time under the private regime.

The key theoretical prediction of our model is that an increase in the share of private to public expenditure on health care results in an increase in income inequality. The relationship plays out by pivoting on the effect of the share of private to public health care spending on the longevity of individuals.

Empirically, we test this prediction using data on the relative demand from private versus public sources of vaccines. We focus on vaccines since they are essential in determining longevity of individuals. We use Indian data from the National Sample Survey Organization (NSSO). The Indian government initiated the Expanded Programme on Immunization (EPI) in 1978 and the Universal Immunization Programme (UIP) in 1985, to reduce morbidity, mortality and disability from diseases, by providing free vaccination services to eligible children. The UIP started vaccination against BCG (Bacillus Calmette–Guérin), polio, DPT (Diphtheria, Pertussis and Tetanus) and measles in the year 1985 (Lahariya, 2014). We use the vaccine information from 42nd NSS Round, corresponding to the year, 1986-87, one year after the introduction of the UIP in India. We use this as the baseline year and study the corresponding regional inequality measures over the period 1987-88 to 2011-12.

We create proxy measures of the demand for public and private sources of vaccine providers in 76 regions of India. We find that the relative demand for measles vaccine varies considerably across the regions- from 100% public provisioning in Sikkim to around 50% public provisioning in Northern Inland Andhra Pradesh during 1986/87. We combine this with regional inequality measures constructed from quinquennial household consumption surveys conducted by the NSSO for the years 1987 to 2012 to assess whether a higher relative share of private vaccine provision results in subsequently higher inequality.

Our estimates using ordinary least squares (OLS) shows that a higher relative share of private sources of vaccination is associated with an increase in inequality. In particular, our estimates imply that a one standard deviation increase in the private-public share of vaccine provision results in a 1.5 percent increase in inequality, an estimate that is robust to alternate measures of inequality- the Gini, the logarithm of variance and the variance of logarithms (Cowell 2011). Recognizing that it would also be important to consider the private share in other dimensions of health care, we test the robustness of our results to the inclusion of variables such as prenatal and postnatal care. Our estimates remain robust to this inclusion. In addition, our results remain robust to a battery of other specification checks.

We recognize the possibility that initial government investments in vaccines may be higher in regions with high mortality rates. In particular, if government investments in vaccine provision are selectively higher in the low life expectancy areas, then the share of private to public investments should be systematically lower in the low-life expectancy areas relative to the high-life expectancy areas. Similarly, if the government seeks to reduce inequality, its investments may be higher in areas with higher inequality. Both of the aforementioned possibilities must result in a negative cross-sectional correlation between the ratio of private to public investments and income inequality. Thus, non-random Government investments across regions should result in a downward bias (towards the null hypothesis of no effect) on our estimated effect of the share of private to public investments in vaccines on subsequent income inequality.

To address this empirical challenge, we use an instrumental variables (IV) approach. We use the relative share of demand from private to public sources of the polio vaccine as our instrumental variable. Our identifying assumption is that administration of the polio vaccine does not directly affect mortality and hence does not directly affect our primary outcome-inequality. Our IV estimates corroborate our OLS findings and suggest that a one standard deviation increase in the private share increases income inequality by 2-3 %. A potential threat to the validity of our IV is that polio vaccine could affect disability and hence directly affect income (and inequality). We empirically test this possibility, and fail to reject the hypothesis that the private share of vaccines is not associated with disability.

This paper is linked to a select literature that has sought to examine the link between health and income inequality. Chakraborty and Das (CD) (2005) introduce endogenous and accidental bequests in an otherwise standard overlapping generation's model with production; in particular, the probability with which a young agent survives into old age depends on the private health investment made by the young. Owing to lower longevity, children from poorer households are more likely to receive low bequests and the resultant wealth effect sets off a cycle of poor health and income.

Lahiri and Richardson (2008) extend the (CD) framework to allow individuals vote on the division of tax revenues between public health spending and a lump sum transfer and examine its impact on wealth inequality. Our paper complements both these papers. The key linkage between generations in our model occurs through parental investment in the progeny's health and we abstract away from issues related to accidental bequests.

Our work is also related to Dottori (2009) who develops an overlapping generation model and examines separately the dynamics of income inequality over time under public and private health regimes. Unlike Dottori, we consider a "mixed or a hybrid economy" with both public and private expenditures and focus on how the relative shares of these expenditures affect income inequality. Further, consistent with our empirical analysis the focus is more on cross sectional income inequality. Most importantly, the aforementioned literature on health is largely purely theoretical. Our paper is one of the few studies that provides empirical evidence on the effect of the relative share of private health expenditure on cross sectional income inequality.

In summary, our results imply that a higher share of public health investments in vaccines may also result in reducing key economic outcomes such as income inequality. The rest of the paper is structured as follows: Section 2 sets up the model. Section 3 describes the economy under homogenous agents while Section 4 illustrates the same for heterogeneous agents and carries out a simple simulation exercise. Section 5 presents our empirical analysis while Section 6 describes our empirical results. Finally, Section 7 contains the concluding remarks.

2 The Model

Our model extends Glomm and Ravikumar's (1992) two-period overlapping generation's framework to include endogenous longevity. We abstract away from issues related to fertility or population growth and assume that at the end of one's youth an individual gives birth to a single offspring. Individuals born at time period t have identical preferences over leisure when young, consumption and the opportunity to invest in health of their offspring when old. Formally, the preferences of an individual born at time t is represented by

$$\mathrm{U} = \ln(n_t) + \phi(x_t)[\ln(c_{t+1}) + \alpha \ln(x_{t+1})] \quad (1)$$

where n_t is leisure at time t, c_{t+1} is consumption at time $(t+1)$ and the parameter α captures parental altruism. We term $\phi(.)$ as the longevity function, which depends on the health input, x provided by the parental generation. This health input, which is a composite good, is obtained as a Cobb-Douglas function of public and private health expenditures given by

$$x_t = \eta h_t^q H_t^{1-q} \quad (2)$$

where H denotes per capita public health expenditure and h denotes agent's private health expenditure. The parameters q and $(1-q)$ represent the share of private and public health expenditure of the overall health expenditure respectively. The longevity function ϕ is weakly increasing and concave in health input and satisfies

$$\phi(.) \text{ with } \phi(0) = 0;\ \phi' \geq 0;\ \phi'' \leq 0;\ \lim_{x \to \infty} \phi(x) = \bar{\phi} \leq 1$$

Following Chakravarty and Das (2005), we assume this function is given by:

$$\phi(x) = \begin{cases} Ax^{\epsilon} & for\ x < \bar{x} \\ \bar{\phi} = A\bar{x}^{\epsilon} & \text{for } x \geq \bar{x} \end{cases} \quad (3)$$

The parameter $\bar{\phi}$ denotes the maximum longevity as a fraction of the adult life (under the current medical technology $A > 0$), $(\bar{x}, \bar{e})$ are the corresponding critical level of health input and earnings and ε is a parameter that lies between (0, 1). When young, individuals allocate n_t units of their time endowment towards leisure and the remaining towards accumulating human capital. Parental knowledge and health inputs are also critical inputs in our human capital accumulation equation. Formally, the young individuals at time t accumulate human capital, e_{t+1} according to,

$$e_{t+1} = \xi(1 - n_t)e_t^{1-\nu} x_t^{\nu} \quad (4)$$

where e_t is the stock of human capital of the parent, ξ denotes the productivity parameter associated with human capital accumulation. The income of the individual during the second period of life is equal to the stock of human capital, e_{t+1}. The importance of parental knowledge as a factor in the process of human capital accumulation is a feature that has been well documented. The seminal work by Becker and Tomes (1979) attributes intergenerational income persistence not only to genetic factors but also to parental human capital. Recent work by Black and Devereux (2011) highlights the link between parental human capital and income persistence.

The effect of health inputs on human capital accumulation is also well established. Numerous studies have shown that poor health adversely affects cognitive skills, productivity and educational outcomes. Currie and Hyson (1999) use British cohort data and find a positive relation between birth weight and educational outcomes. More recently, Figlio et al. (2013) using US data provide evidence on the long-term effects of birth weight on cognitive development. They find that increases in birth weight can have a positive effect on cognitive skills, and hence on adult earnings.

Public health expenditure per capita, H_{t+1} is financed by income tax,

$$H_{t+1} = \tau_{t+1} E_{t+1} \tag{5}$$

where τ_{t+1} is the income tax rate imposed on the adults in period $t+1$ is determined in each period through majority voting; $E_{t+1} = \int e_{t+1} \, d\, F_{t+1}(e_{t+1})$ is the per capita earnings as of period $t+1$ and F denotes the cumulative earnings distribution. Finally, the budget constraint of an individual is given by:

$$c_{t+1} + h_{t+1} = (1 - \tau_{t+1})e_{t+1} \tag{6}$$

2.1 Individual's optimization

The optimization follows a two-step maximization procedure. In the first step, taking as given $\{e_t, x_t, H_{t+1}\}$, the agents utility maximization problem is to choose (n_t, c_{t+1}, h_{t+1}) to maximize (1) subject to (3) and (6). Equivalently, the agent chooses n_t and h_{t+1} to maximize:

$$\max_{n_t, h_{t+1}} \mathrm{U} = \ln(n_t) + \phi(x_t)\left[\ln(1-\tau)\{\xi(1-n_t)e_t^{1-\nu}x_t^{\nu}\} + \alpha \ln\left(\eta h_t^q H_t^{1-q}\right)\right]$$

Note that the parental health input x_t is a predetermined variable for the generation born at t. Hence, the optimization problem is concave and well-behaved with the introduction of endogenous longevity. The individual's optimization problem satisfies the first-order conditions

$$n_t = \frac{1}{1 + \phi(x_t)\left(1 + \frac{h_{t+1}}{c_{t+1}}\right)}; \quad \frac{1}{c_{t+1}} = \alpha q \frac{1}{h_{t+1}}$$

Combining these equations, we get an expression for n_t :

$$n_t = \frac{1}{1 + \phi(x_t)(1 + \alpha q)} \tag{7}$$

Equation (7) implies that the time allocated to leisure varies inversely with both the health input and the share of private expenditure in the overall health expenditure or $\frac{dn_t}{dx_t}, \frac{dn_t}{dq} \leq 0$. The intuition behind (7) is best understood by considering two extreme cases (a) $q = 1$, a pure private health regime and (b) $q = 0$, a pure public health regime. Using (7), the corresponding expressions for n under these pure regimes can be rewritten as

$$n_t^{Private} = \frac{1}{1+(1+\alpha)\phi(h_t)} \tag{8}$$

$$n_t^{Public} = \frac{1}{1+\phi(H_t)} \tag{9}$$

Comparing (8) and (9) it is easy to see that for a given level of health expenditure, the time allocated to leisure is higher under the pure public regime when compared to the pure private regime. Essentially, unlike in the private health regime, individuals under the pure public regime do not factor health investment on their progeny. They therefore compare only the marginal benefit of leisure with marginal cost of future consumption. The lower opportunity cost of leisure, results in individuals underinvesting in education under this regime. This in turn implies that the higher the share of private expenditure in an economy, the lower will be the time allocated to leisure; put differently, $\frac{dn_t}{dq} \leq 0$.

We next proceed to solve for the optimal tax rate τ. As already discussed public health expenditure is provided by government, which levies a proportional tax τ on wage income of the old determined through majority voting. Essentially we assume that the young generation is too young to be allowed to vote. Following Glomm and Ravikumar (1992), we solve for the agent's preferred tax rate by maximizing the second period utility given by

$$\ln\left((1 - \tau)\{\xi(1 - n_t)e_t^{1-\nu}x_t^{\nu}\}\right) + \alpha \ln(\eta h_t^q (\tau_t E_t)^{1-q}) \tag{10}$$

Note that the old agent's choice of tax rate does not alter his income but affects the fraction of income he can consume. By duality, the outcome of this optimization also minimizes the cost of providing a given level of health input x. The maximization over τ yields the following first order conditions:

$$\frac{e_{t+1}}{c_{t+1}} = \alpha(1-q)\frac{1}{\tau} \tag{11}$$

Combining the budget with (7) and (11), we are able to solve for the preferred tax rate in terms of the parameters

$$\tau = \frac{\alpha(1-q)}{1+\alpha} \tag{12}$$

Since the preferred tax is independent of the income, this would be the tax rate under our voting equilibria. Equipped with these results, we can express c_t and h_t as constant fractions of e_t as below:

$$\begin{aligned} c_t &= \frac{1}{1+\alpha} e_t \\ h_t &= \frac{\alpha}{1+\alpha} q e_t \end{aligned} \tag{13}$$

Both second period consumption and health investment by the adult are a rising function of human capital. From equation (13), it follows that health investment varies positively with the degree of altruism, α. Substituting equations (7) and (12) into equation (4) obtains

$$e_{t+1} = \begin{cases} \xi \dfrac{\theta x_t^{\epsilon}}{1+\ \theta x_t^{\epsilon}} x_t^{\nu} e_t^{1-\nu} & \text{for } x_t < \bar{x} \\ \xi \dfrac{\theta\, \bar{x}^{\epsilon}}{1+\ \theta\, \bar{x}^{\epsilon}} x_t^{\nu} e_t^{1-\nu} & \text{otherwise} \end{cases} \tag{14}$$

where $\theta \equiv A(1+\alpha q)$.

3 Homogeneous case

The objective of this section is to analyze the paths of earnings when individuals are homogeneous. When all households are identical, $e_t = E_t$ and $\frac{h_t}{H_t} = \frac{q}{(1-q)}$ and the health aggregate is linear in earnings

$$x_t = \psi e_t$$

where $\psi = \frac{\eta_0 \alpha}{(1-\alpha)}$.[1]

The equation describing the evolution of human capital in the economy is given by,

$$H(e_t) = e_{t+1} = \begin{cases} \xi \dfrac{\theta \psi^{\varepsilon+\nu} e_t^{1+\varepsilon}}{1+\theta \psi^{\varepsilon} e_t^{\varepsilon}} & \text{for } e_t < \bar{e} \\ \xi \dfrac{\theta \psi^{\varepsilon+\nu} \bar{e}^{\varepsilon} e_t}{1+\theta \psi^{\varepsilon} \bar{e}^{\varepsilon}} & \text{otherwise} \end{cases} \tag{15}$$

Notice, it follows from equation (15), $H'(\mathrm{e}) > 0$ for any e; $H''(\mathrm{e}) > 0$ for $e < \bar{e}$; but $H''(e) = 0$ for $e \geq \bar{e}$. Therefore, the income locus has a convex portion till the critical human capital, $\bar{e}$ is reached, beyond which the locus starts following a linear path. Next we analyze the dynamics under the three regimes. The results are summarized in the proposition below.

Proposition 1. *Under the assumption of homogeneous individuals in the economy with the same initial level of income,*

1. *The dynamic system described by eq (15) may possess at most two fixed point equilibria in general.*
2. *One is stable, leading to the poverty trap e^{φ}. The other is unstable, high income equilibrium e^{u}. When initial income is low and $e_0 < e^{u}$, the economy converges to e^{φ}. For $e_0 > e^{u}$, the economy enters the endogenous sustained growth path, in which the long-run growth rate is $g = \xi \frac{\theta \psi^{\varepsilon+\nu} \bar{e}^{\varepsilon}}{1+\theta \psi^{\varepsilon} \bar{e}^{\varepsilon}}$.*

Proof. See Appendix A.1

Proposition 1 is best understood using Figure 2A. Clearly, the economy is characterized by two fixed point equilibria, e^{φ} and $e^{u} > 0$. Crucially the initial conditions determine if the individual ends up on a sustained growth path or a low level equilibrium.

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[1] Given (12) and (13), the indirect function for health input is $x_t = (\psi_0 \eta) e_t^{q} E_t^{(1-q)}$ where $\psi_0 = q^{q}(1-q)^{(1-q)}$. This means that a different choice of q not only shifts the composition of private and public health expenditure, but also affects the level of health status, x. We offset this composition effect by setting $\eta = \eta_0 / (q^{q}(1-q)^{(1-q)})$ so that the composition of private and public health expenditure does not affect the size of health input for a given total expenditure. As a result, $\psi = \psi_0 \eta \equiv \frac{\eta_0 \alpha}{1-\alpha}$.

Proposition (1B) shows that any representative family dynasty with an initial income, $e < e^{u}$ converges to $= e^{\varphi}$. Once income crosses the threshold of e^{u}, one enters the path of sustained endogenous growth. The fixed point, e^{u}, is therefore unstable. Intuitively, if a family starts off with an income below the threshold in either regime, investment in health is low. The consequent reduction in longevity causes the young to underinvest in human capital. This results in a vicious cycle of poor health and low income.

Proposition 2. *Under the assumption of homogeneous individuals in the economy with the same initial level of income,*

1. *Per capita income is increasing in the share of private health expenditure,* q.
2. *The threshold income level,* e^{u} *above which the economy enters the sustained endogenous growth path is decreasing in* q.
3. *The long-run sustained growth rate is increasing in* q.

Proof. See Appendix A.2

In order to build intuition it is useful to contrast the dynamics in our "mixed or hybrid regime" characterized by both public and private health expenditures with those obtained in "pure" economies in which are characterized by the presence of either private or public health expenditures. It is easy to see from (15) that the income locus under the pure private regime is given by

$$J(e_t) = e_{t+1} = \begin{cases} \xi \dfrac{A(1+\alpha)\psi^{\epsilon+v} e_t^{1+\epsilon}}{1 + A(1+\alpha)\,\psi^{\varepsilon} e_t^{\epsilon}} & \text{for } e_t < \bar{e} \\ \xi \dfrac{A(1+\alpha)\psi^{\epsilon+v}\bar{e}^{\epsilon} e_t}{1 + A(1+\alpha)\,\psi^{\varepsilon}\bar{e}^{\epsilon}} & \text{otherwise} \end{cases}$$

Notice that $J'(e) > 0$ for any e; $J''(e) > 0$ for $e < \bar{e}$; but $J''(e) = 0$ for $e \geq \bar{e}$. Similarly, under the public regime the income locus is given by

$$M(e_t, E_t) = e_{t+1} = \begin{cases} \xi \dfrac{A\psi^{\epsilon+v} e_t^{1+\epsilon}}{1 + A\,\psi^{\varepsilon} e_t^{\epsilon}} & \text{for } e_t < \bar{e} \\ \xi \dfrac{A\psi^{\epsilon+v}\bar{e}^{\epsilon} e_t}{1 + A\,\psi^{\varepsilon}\bar{e}^{\epsilon}} & \text{otherwise} \end{cases}$$

It follows that, $M'(e) > 0$ for any e; $M''(e) > 0$ for $e < \bar{e}$; but $M''(e) = 0$ for $e \geq \bar{e}$. Therefore, as in the hybrid and the private regime, the income locus has a convex portion till the critical human capital, $\bar{e}$ is reached, beyond which the locus starts following a linear path.

Figure 2B plots the income loci under the three regimes. The dotted red line represents income locus under the hybrid regime, the solid blue line the private income locus and the dotted yellow line represents the public income locus. If individuals start off with the same human capital under the three regimes, human capital accumulation under the pure private regime will always be greater than that in the pure public regime.

The young under the private regime take into account the fact that their health investment impacts the income of their progeny. This in turn leads to higher time investment for accumulating human capital compared to the public regime. As individuals choose to accumulate less human capital under the public regime, the economy requires higher initial income to attain the sustained endogenous growth path.

Since the hybrid regime is a composite of the public and private regimes the "take off" income at which the economy enters a sustained growth path lies between the pure public and private regimes. Once the income crosses the critical level and attains endogenous growth, the long-run income growth rate becomes constant under all three regimes. This growth rate under the hybrid regime lies between those obtained under the private and public regimes. Once again this is due to the fact that under the private regime health investments are fully internalized unlike the hybrid and the public regimes.

4 Heterogeneous case

Having characterized income dynamics under the homogenous case, we are now set to evaluate and compare income inequality for alternative values of q under heterogeneous agents. We first derive the equilibrium law of motion for human capital when agents are heterogeneous. Notice, that unlike the homogenous case, here, the indirect function for the health status takes both individual and average earnings as its arguments:[2]

$$x_{it} = \psi e_{it}^{q} E_t^{1-q}$$

The corresponding equilibrium law of motion for human capital is given by

[2] This section introduces the subscript i to denote an individual household so that household and economy level variables are distinguished clearly.

$$e_{it+1} = \begin{cases} \xi \dfrac{\theta\psi^{\varepsilon+\nu} E_t^{(1-q)(\varepsilon+\nu)} e_{it}^{q(\varepsilon+\nu)+1-\nu}}{1+\theta\psi^{\varepsilon} e_{it}^{q\varepsilon} E_t^{(1-q)\varepsilon}} & \text{for } \left\{ \dfrac{e_{it}}{\bar{e}} < \left[\dfrac{E_t}{\bar{e}}\right]^{\left(\frac{q-1}{q}\right)} \right\} \\ \xi \dfrac{\theta\psi^{\varepsilon+\nu} \bar{e}^{\varepsilon} E_t^{\nu(1-q)} e_{it}^{1-\nu(1-q)}}{1+\ \theta\psi^{\varepsilon}\ \bar{e}^{\varepsilon}} & \text{otherwise} \end{cases} \tag{16}$$

While many of our results are derived analytically, we rely on numerical computations to illustrate the impact of q on cross sectional income inequality. Since closed-form solutions are difficult to obtain, our endeavour is to provide examples showing how income inequality is impacted by different values of q. We emphasize that this section is not intended to be a comprehensive calibration exercise; we only wish to illustrate some qualitative features of the model using plausible parameterization of the model.

We start by specifying the exogenous income distribution and assigning values for parameters. We assume a lognormal income distribution with mean and standard deviation of the logarithm of income being μ and σ respectively. This is commonly assumed in both empirical and theoretical literature. Other parameters of the model include α, which is the weight of health relative to consumption in the utility function, q, the parameter measuring share of private expenditure in total health expenditure, ϵ the parameter that captures the elasticity of longevity increase with respect to health input, ν which measures the effect of childhood health investment on human capital production and the two scale parameters A and ξ. In the baseline calibration, we calibrate these eight parameters to match certain characteristics of the Indian data in the period spanning 1985-2007.

First, μ and σ are calibrated to match the Gini coefficient for Indian households in 1985. For India in 1985 the Gini coefficient was around 0.3 (Pal and Ghosh (2007)). Using this we set the log-mean to $\mu = 7$ and log-standard deviation to $\sigma = 0.55$. Given our utility specification where α measures the weight on health relative to consumption we set α equal to 0.05 as this would be broadly consistent with the share of health in aggregate consumption expenditure. Next, we set $q = 0.7$ to match the share of private health expenditure in total health expenditure in the Indian data (World Bank, authors own calculations using NSSO data).

We assume that one period in our model corresponds to 20 years. This is based on our assumption that the young generation cannot participate in voting. This would mean that we would need to introduce at least two additional periods to make the model more realistic. However, as emphasized earlier the objective of the simulation exercise is qualitative and not quantitative and therefore we stick to the two period model. The dynamics obtained will provide the foundation for the empirical analysis carried out in the next section.

The underlying parameters in the longevity function are recovered by the following steps. First, for simplicity, the age 100 is taken the maximum age. Then the fraction of the adulthood life-expectancy, ϕ, is calculated by

$$\phi_t = \frac{\text{life expectancy at birth at t}-20}{100-20}$$

Data on life expectancy at birth is obtained from the World Bank. Consistent with our model, the above specification implies that all improvements at life expectancy at birth can be attributed to an increase in longevity during adulthood. Finally, we estimate ϵ and A by the following ordinary least square model:[3]

$$\log \phi_t \ = \ \log A + \epsilon \log x_t + u_t$$

The parameter ξ is calibrated to match the long-run annual growth of 2 percent and υ is set at 0.1. Table 1 reports the calibrated values.

4.1 Simulation results

This section reports the results from our simple calibration exercise. Specifically, we examine the path of income inequality under different values of q. Figure 3 traces the path of Gini coefficient under different values of q. It is evident from the figure that economies with a higher share of private health expenditure, q, are associated with a higher income inequality. Moreover, economies with relatively high q's exhibit rising inequalities over extended periods of time. It takes more than 10 generations or 200 years before the earnings inequality eventually declines. This key result in this section is summarized below

Result: *The cross-section earnings inequality is non-decreasing in the private share of health expenditure,* q.

The intuition is best understood by focussing on the extreme cases of $q = 0; q \ = \ 1$. Notice, from (16), for $x_{it} < \bar{x}$, $\frac{\partial e_{it+1}}{\partial e_{it}} > 0$, $\frac{\partial^2 e_{it+1}}{\partial e_{it}^2}|_{q=0} < 0$ and $\frac{\partial^2 e_{it+1}}{\partial e_{it}^2}|_{q=1} > 0$. Also for $x_{it} \geq \bar{x}$, e_{it+1} is concave in both E_t and e_{it}. These imply that while any initial differences

[3] In this process, we arbitrarily choose η_0= 0.5429≅ $0.7^{0.7}0.3^{0.3}$ so that η drops out in the health aggregate for the baseline case. This does not affect results because η_0 and A are not separately recoverable from observable data.

in income are exacerbated under the private regime, these differences are reduced over time under the public regime. The above results which can be generalized under reasonable parameter values for a broader range of q, imply that cross-section income inequality is non-decreasing in q.

Essentially, under high values of q, the hybrid regime behaves like the pure private regime in the region $x_t < \bar{x}$. Here, higher initial income by facilitating greater private investment in health results in faster income growth rate. This means that any initial income inequality is exacerbated over time. By contrast, under low values of q the economy behaves more like a pure public regime. In this scenario, since health care provision is the same for all, low income individuals experience faster growth than high income individuals owing to diminishing returns for a given level of per capita income. This results in declining inequality.

Finally, for a sufficiently high critical mass of $x_{it} \geq \bar{x}$, there is a decline in income inequality in an economy over time. This follows from the fact that under this scenario e_{it+1} is concave in both E_t and e_{it}. Intuitively, since a significant proportion of the population reaches maximum longevity, decreasing returns to human capital accumulation sets in.[4] However, as seen in Figure 3, despite the narrowing income inequality in this high income range, the cross-sectional inequality difference still persists. The inequality gap closes only asymptotically.

5 Empirical Analysis

In this section we examine the impact of public versus private health investments on inequality. Our key theoretical prediction is that public and private health investments affect longevity differentially and thus may have varied effects on inequality. We specifically test the hypothesis that a higher share of private to public health expenditures leads to higher income inequality.[5] One challenge in estimating this relationship is that health investments may be non-randomly assigned with the government choosing to invest more in areas with poorer health outcomes. Further, since the effects of health investments on inequality will take time to materialize we need access to data over a long time period.

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[4] This result is true in general for $q < 1$. For $q = 1$, it is easy to show that the dispersion in income does not decline overtime. We show this in an earlier version of the current paper, available on request (also see Dottori (2009)).

[5] This specification is consistent with our theoretical results since the private-to-public health expenditure, $q/(1-q)$ is increasing in q.

We address the potential non-random placement of vaccines is addressed using an instrumental variable approach. We also obtain data from multiple rounds of cross-sectional household surveys collected by the National Sample Survey Organization (NSSO) in India to construct a longitudinal regional-level data that includes information about the relative private to public investments in vaccines and measures of inequality with the entire data spanning a long period of time (1986-87 to 2011-12). Next, we discuss in detail the data and variables used in our analysis followed by a description of the empirical methods employed.

5.1 Data & Variables

The NSSO quinquennially conducts consumption expenditure surveys for households across the nation. We use five such survey rounds (43rd, 50th, 61st, 66th and 68th rounds), spanning 1987 to 2012.[6] Like many other papers, we prefer not to use the 55th Survey Round (1999-2000) due to differences in the recall periods (Himanshu, 2007).[7] We base our inequality computations on the uniform recall period of 30 days across the five thick rounds. Our data on 2,671,022 individuals, aggregated at the regional level, spans a period of around 25 years. Regions are aggregates of districts with similar geographical features and population densities. We are able to follow around 76 regions across the five survey rounds.[8] In every survey round, we map the individual districts with their respective original regions. For the newly formed districts, we identify the year and source of bifurcation and identify the corresponding region from the baseline survey. Together, these regions approximately cover the entire nation. The key variables across the quinquennial surveys are finally pooled together, yielding 379 observations.

Since our data does not have direct information on the private versus public investment in vaccines, we create a proxy measure based on demand of vaccines from private versus public facilities. The key assumption here is that this relative demand is a good proxy for the relative investments made in public and private sources. More broadly, we assume that if there are more households seeking vaccination at the public facility than in a private facility in a region, then there are more health investments by the government compared with the health investments made by the private sector in the region.

[6] NSS Round 43rd represents 1987-1988, 50th Round represents 1993-94, 61st Round represents 2004-05, 66th Round represents 2009-10 and 68th Round represents 2011-12.
[7] During the 55th round, expenditure on some consumption goods were reported on a 7-day recall period. This makes comparisons difficult.
[8] Only one region, Jhelum Valley in Jammu & Kashmir is not available for analysis 50th NSS Round. We use information on 76 regions for all the other survey rounds.

Household level data on sources for the vaccines can be obtained from the 42nd NSS round in 1986-87. During that survey, households were asked whether the children received particular vaccines from the government or from private sources (free of charge or at cost) or not received the vaccine at all.

After eliminating all the invalid entries for the respective vaccines, we compute the ratio of the number of individuals, as a percentage of total valid responses on the vaccine, who obtained it from private sources within a region. Similarly, we compute the number of individuals, as a percentage of total valid responses on the vaccine, who obtained the same from public sources, within a region. Using these measures, we construct the ratio of the two to arrive at the relative share of private to public demand for vaccines within the region.

We use three measures of inequality: the Gini coefficient, logarithm of the variance, and the variance of the logarithm (Cowell 2011). For each region-period, we calculate the inequality measures based on the average monthly per capita consumption expenditure (in INR) reported in the NSSO (Please see details in Appendix B). The expenditure data at current prices are converted to constant prices. This is done using aggregate deflators - CPI-AL (at Base year 1986-87) for the rural and CPI-IW (at Base year 2001) for the urban areas respectively (Basole & Basu, 2015).[9] Though it is desirable to use income data for computing the inequality measures, nationally representative data on household income, spanning multiple years is hard to find in the Indian context. As in several other studies, consumption expenditure serves as a proxy for income in our analysis.[10]

Following Mitra & Mitra (2016), we use a set of socio-economic and demographic control variables at the regional levels. In order to derive population estimates, we use the sampling weights provided by the NSSO. In accordance with the Indian Census, the NSS categorizes each region into rural and urban areas. Each household in each survey is accordingly classified as belonging to rural or urban areas. In our analysis, we control for the share of rural population in each region. We use the percentage of Hindu population in a region as a control for religion. The percentage of individuals with secondary education serves as a proxy for education. In order to capture the importance of different social and ethnic groups in India, the households are classified into different social groups. We control for the percentage of individuals belonging to the scheduled caste category as a proxy for the social group. The Scheduled caste represents the officially designated disadvantaged

[9] This data is obtained from the Economic and Political Weekly Research Foundation India Time Series database and the Labour Bureau of the Ministry of Labour & Employment, Government of India.

[10] See Himanshu (2007), Mitra & Mitra (2016).

class of people in India. We also control for the year effects in all the specifications. A data Appendix B provides details on the construction of additional control variables used in the analysis.

5.2 Estimation Strategy

We use the NSS rounds to construct regional-level measures of inequality and the relative demand for private versus public sources of vaccines. We first use ordinary least squares to estimate the coefficients in the following equation:

$$\text{Inequality}_{\text{s,t}} = \alpha + \beta \left\{ \frac{Private\_vac_{s,86/87}}{Public\_vac_{s,86/87}} \right\} + \gamma Z_{s,t} + \text{Year Dummies} + \varepsilon_{s,t} \quad (17)$$

where s and t represent region and year respectively, $\left\{ \frac{Private\_vac_{s,86/87}}{Public\_vac_{s,86/87}} \right\}$ is the relative demand for private versus public sources of vaccines and Z is a vector of socio-economic factors such as religion, education, social group and the share of rural population in a region. We estimate (17) using three alternate measures of the relative demand for private versus public sources of vaccines for measles, DPT and BCG vaccines. Each survey round usually reports the data at rural and urban areas within a state, region or district. We aggregate all variables from the individual to regional levels. The primary empirical challenge in this context lies in the possibility that the relative private versus public investments in vaccines is not randomly distributed across regions. In order to address this challenge, we use a two-stage least squares (TSLS) approach. Consistent estimates of β can be obtained if we have an instrumental variable that is strongly correlated with $\left\{ \frac{Private\_vac_{s,86/87}}{Public\_vac_{s,86/87}} \right\}$ but uncorrelated with $\varepsilon_{s,t}$. One plausible instrumental variable is the region-specific relative demand for polio vaccines which we define as:

$$\text{Instrumental Variable (IV)} = \left\{ \frac{Private\_vac_{s,86/87}}{Public\_vac_{s,86/87}} \right\} \quad \text{for polio vaccine}$$

We argue that this is a plausible instrument for two reasons. First, the instrument is potentially highly correlated with $\left\{ \frac{Private\_vac_{s,86/87}}{Public\_vac_{s,86/87}} \right\}$ for other vaccines, since it is likely that individuals who get for example measles vaccine from private compared to public sources, are more likely to obtain the polio vaccine also from private sources. Secondly, polio affects the muscular functions alone and compromises the quality of life but generally does not affect longevity. Since longevity, in our theoretical model, is the primary channel connecting investments with inequality, we argue that our instrumental variable is uncorrelated with $\varepsilon_{s,t}$. By definition, we cannot test the aforementioned assumption. However, we note that the bias in our OLS estimates should be towards the null since the Government is more likely to make investments in both high mortality and high inequality areas. Therefore, in a cross-sectional sense regions with higher private to public share of vaccines should also be those where there is lower inequality.

Although non-random government investments across regions could potentially result in a downward bias of our results, it is also possible that individuals in regions where income inequality is lower also share preferences for health systems in which public expenditure is more relevant, therefore producing an upward bias. In order to assess the validity of this concern, we use the 2002 data from the National Sample Survey Organization (NSSO) to create an indicator variable that equals one if the individual reports that he/she perceives that the quality of the public health facility is poor. The indicator variable takes on the value zero otherwise. We then run a regression where the independent variable is the private-public mix of the polio vaccine in 1987-88 and also separately the private-public mix of the polio vaccine in 1993-94.

In addition, our IV (private to public ratio of vaccine provision) could be potentially correlated with the error term in equation (17) due to a correlation between the IV and disability. More specifically, the IV may be correlated with disability and hence earnings and earnings inequality. In order to assess the threat to the validity of our IV, we use data from the 2002 disability survey collected National Sample Survey Organization (NSSO) to construct an individual-specific measure of whether or not an individual was disabled. We run a regression of disability on our baseline measure of the private-public mix in the provision of the polio vaccine to assess the strength of the correlation between the two variables. Details of both the NSSO data on disability and preferences and the details of the construction of the relevant variables is described in Appendix B.

6 Empirical Results

Table 2 provides the summary statistics of the variables used in our analysis. The Gini coefficient and the logarithm of variance are the inequality measures. The ratio of the demand from private to public sources of vaccines is expressed separately for measles, DPT and BCG. We note that there is considerable variation in the key dependent variable (inequality) and the independent variables (measles, DPT and BCG). The Gini and logarithm of variance vary across regions. Figure 4 panels A-D represent the distribution of regions according to the share of private to public sources of demand for vaccination. We observe regional variation for all vaccines but most regions to not have any representation of the private sector in meeting the demand for vaccines. The dominant government role in the provision of vaccines is almost completely flipped in the case of health care provision in other areas such as pediatric care, prenatal and postnatal care. The ratio of private to public demand is about 0.8, more than 5 times the ratio observed for vaccines. The statistics are presented at various levels. In Section A, we present data from our baseline year (1986-87) for each of the 76 regions. In Section B we present statistics on our outcomes (inequality) as well as other control variables that vary over time. These statistics are therefore at the region-year level. Finally, in Section C we present summary statistics from individual level data on both disability and preferences that will be used in empirical tests of the validity of our design.

Table 3 presents results from an OLS regression after pooling observations of the years. The findings in column 1 of panel A suggests that a one standard deviation increase in the private-public provision of vaccines results in a 1.5 percent increase in the Gini coefficient. In column 2 we find that these results are robust to the inclusion of other control variables at the state-region level (full list of control variables is provided in the footnote to Table 3). In column 3, we also control for the private-public mix of hospitalisation in case of child ailment. We find that the effect of the private-public mix in vaccine provision continues to remain robust to this inclusion. Column 4 of panel A contain results when the logarithm of variance is used as a measure of inequality. We find that a one standard deviation increase in the private-public provision of vaccines results in about a 3 percent increase in inequality, and the results remain robust when we control other variables (column 5) and non-vaccine health indicator (column 6).

We choose to focus on the private to public share of vaccine provision in this paper, but panel B of Table 3 provides evidence that this focus is perhaps not too restrictive. In panel B, we present the effect of private-public mix of non-vaccine sources of care on inequality. We find that the effects of the non-vaccine variables is relatively small- ranging from about one-eight (for effects on the Gini) and one-fifth (for effects on log variance) of the effect observed for vaccines.

Although the coefficients for the Gini in panel A of Table 3 are robust to the inclusion of other control variables, in the case where we use the logarithm of variance, the coefficients decrease slightly as we move to a specification that includes control variables. This finding suggests that the private-public mix of vaccines is not randomly distributed across state-regions. We therefore also present results from an instrumental variable approach that uses the private-public mix of the polio vaccine as an instrumental variable. The IV results in Table 4 suggests that a higher private to public mix in vaccine provision results in higher income inequality. As expected the standard errors of the point estimates of the IV regressions are higher than that of OLS but the point estimates are higher and so the estimates remain statistically significant. Further, the results are robust to the inclusion of other control variables. Our IV regressions have high first-stage F statistics, above the required threshold value of 10 (Staiger and Stock 1997). The IV results suggest that a one standard deviation increase in private-public mix of measles increases the Gini coefficient by 2.2 percent and the logarithm of variance by 4.3 percent. The estimates are similar for the case of DPT. For BCGs, a one standard deviation increase in the private-public mix increases the Gini coefficient by about 3 percent and the logarithm of variance by approximately 5.8 percent. As noted previously due to the nature of selective investments in vaccines, our OLS estimates are plausibly lower-bound estimates. Our OLS (Table 3) and IV estimates (Table 4) confirms this intuition with the IV point estimates being slightly larger than the OLS estimates.

6.1 Robustness Check

6.1.1 Stability of coefficients over time

Our empirical strategy estimates the relationship between "baseline" measure of the relative intensity of private to public demand for vaccines calculated using 1986-87 data and subsequent inequality measures (1987-88 to 2011-12). Our regression results presented in tables 3 and 4 include the pooled data over all the years. In Table 5, we test the sensitivity of our estimates to including only specific years of data- starting from only including the most recent year (2011-12) in column 1 and successively adding years in columns 2, 3 and 4. The OLS estimates for both the Gini and the logarithm of variance suggests a high degree of robustness for the coefficient on the private-public mix of measles coverage. The coefficient on the Gini is less robust when we only include the most recent data point, but we note that this may be due to the very high standard error on the coefficient estimate- the standard error in column 1 (0.035) is more than double the standard error in column 4 (0.017). Other than this exception, the coefficients on the Gini also remain robust to using different years in analysis. The IV estimates for measles, DPT and BCG using the logarithm of variance all suggest that our estimates are not very sensitive to the time period used in our analysis. Once again, we note that the point estimates all remain relatively stable, but the higher standard error (plausibly a result of the low sample size) when using the most recent year renders the coefficient statistically insignificant. Indeed, to the extent that using more current years data reduces the possibility of reverse causality, the findings bolster our confidence that our estimates in Tables 3 and 4 may be interpreted as causal effects of the private-public mix in the provision of vaccines on income inequality.

6.1.2 Stability of private-public mix of vaccine coverage

Our primary regressions use the baseline (1986-87) distribution of the private-public mix. However, it is possible that the baseline distribution of the relative share itself changes over time if Governments (or private providers) choose to make temporal changes in investments. To assess this possibility, we first plot the ratio of private to public vaccine demand for BCG vaccines in 1986-87 against the similar measure calculated in 1995-96. Figure 5 shows this scatter. We find that there are two striking departures where the data point lies away from the 45 degree line suggesting that, in these two regions, there is little stability in the private to public demand for BCG vaccines.

We assess the sensitivity of our results when we drop the two outlier regions from our analysis. When we control for the complete list of variables (similar to column 3 of Table 4), the point estimate on BCG is 0.083 (standard error = 0.033) in the case of the Gini and 5.050 (standard error = 1.743) in the case of the logarithm of variance.[11]

6.1.3 Bias on the estimated coefficient on relative private share in the provision of vaccines

We previously noted that direction of bias in the OLS estimates should be towards the null since governments is more likely to invest in the poorer, high mortality areas and the private sector is more likely to invest in the richer, low-mortality areas. However, it is possible that individuals in regions where income inequality is higher also share preferences for health systems in which public expenditure/investment is less relevant. In particular, it is possible that individuals residing in high income inequality areas have lower preferences for publicly

[11] Due to data constraints, we are unable to conduct sensitivity analysis for measles and DPT.

provided health care. In this case, there will be a positive correlation between the private-public mix and income inequality, generating an upward bias in our OLS specifications. We assess the strength of this hypothesis by examining whether regions of higher income inequality also have lower preferences for government provided health care. The NSSO survey data in 2004-05 has a specific question on whether the individual believes that the government health care facilities are of poor quality. We create an indicator variable equal to 1 if so, and 0 otherwise. We run a regression of this variable on income inequality. The results are presented in Table 6 with the columns denoting estimates with and without adjusting for other control variables. We find that inequality levels are not correlated with preferences when we use the baseline inequality measure, regardless of the inequality measure. When we use inequality measures as of 1993-94, we find insignificant coefficient on the Gini, but find that higher variance in the logarithm of income (higher income inequality) is associated with a greater preference for government public facilities. Overall, our results suggest that we could continue to treat the OLS estimates as providing lower bounds.

6.1.4 Threats to validity of the instrumental variable

The instrumental variable we use is the private-public mix of the polio vaccine. Although we show (using our first stage F-statistic) that the IV is strongly correlated with the main independent variable, it is possible that the IV is correlated with disability and hence earnings and earnings inequality. The polio vaccine's primary purpose is to prevent a disability and disability is a known correlate of lower earnings. We therefore examine whether our IV is correlated with disability. In 2002, the NSSO conducted a large national survey to understand the prevalence and characteristics of disability in India. We use this data and merge it with our instrumental variable-our baseline measure of private-public mix of provision of the polio vaccine. The results are presented in Table 7 and suggest that there is no correlation between the share of the private sector in the vaccine provision and disability, a result that bolsters confidence in the validity of our IV.

7 Conclusion

In this paper we seek to establish both theoretically and empirically the link between the relative shares of public and private health expenditures and cross sectional income inequality. In a model where mortality is endogenous and is function of both public and private health expenditures, we show that cross sectional income inequality is non-decreasing in the share of private health expenditure.

We empirically test our theoretical prediction using region-level data from India. Specifically, we examine the manner in which a higher share of the private sector in the provision of vaccines affects income inequality. We use vaccination data on the relative private-public share of vaccine provision in 76 regions in India in the year 1986-87. We also use multiple household-level consumption expenditure survey rounds to construct inequality measures within each region in India for the period spanning 1987-88 through 2011-12. OLS regressions are potentially biased due to non-random investments in vaccines across regions. Using the relative private-public share of the polio vaccine as an instrumental variable approach, we examine the strength of the link between the relative private shares and income inequality in an instrumental variable analysis. Our identification strategy rests on the assumption that Government (or private) investments in the polio vaccine does not affect mortality and hence inequality.

Estimates from both our OLS and IV models suggest that increasing the relative share of private sources of health care provision is associated with an increase in expenditure inequality. More specifically our OLS estimates for measles imply that a 1 standard deviation increase in the relative private share in vaccine provision results in a 1.5 percent increase in the Gini coefficient and a 3 percent increase in the variance of the logarithm of income. Our findings based on the IV analysis suggest that a 1 standard deviation increase in the relative private share results in a 2.2 % increase in the Gini and a 4.3 % increase in the variance of the logarithm of earnings. As noted previously due to the nature of selective investments in vaccines, our OLS estimates are plausibly lower-bound estimates and the higher magnitude of the IV estimates confirms this intuition.

Although we focus on vaccines, we observe that the effects are also robust to the inclusion of the private share in non-vaccine health care investments. Furthermore to the extent that inequality is relatively permanent, we find that our results are also robust to the inclusion of initial income inequality. Our primary results pool observations over the years but in a robustness analysis we examine the sensitivity of our estimates to using cross-sectional "snapshots" of our data and again find that the initial relative private share in vaccines is related to subsequent income inequality.

Given the observational nature of the analysis, the findings are subject to a few limitations. First, it is not possible to confirm the validity of our instrumental variable due to data limitations. In particular, we cannot rule out the possibility that unmeasured factors affect both income inequality and the instrumental variable. Nevertheless, we do posit that the direction of the bias in our OLS estimates is most likely towards the null hypothesis suggesting that our OLS estimates may be considered lower bound estimates. Second, although we have used the demand for vaccines as a proxy for investments in health. It is possible that at the regional-level, demand for vaccines is only an imperfect indicator for actual investments. For example, although a particular region has heavy Government investments in vaccines, the demand for Government sources may be low if households perceive poor quality of the provider. Even so, to the extent that the relative private share in demand measures the relative private share in health investment with random error, our OLS estimates should once again be biased downward towards zero and hence provide a lower-bound estimate of the true effect.

India has recently announced a new National Health Policy that seeks to rapidly increase government investments in the health sector- a move that could increase the percent of government health expenditure in overall GDP from 1.3 percent to 2.5 percent. Moreover, a program titled Mission Indradhanush has been recently launched by the government and seeks to ramp up the childhood vaccination rates to over 90 percent by the year 2020. If these materialize in reductions in poor health outcomes, our findings suggest that the increasing health investments envisaged by the Government of India could play a role in not only improving health but in also lowering subsequent levels of income inequality.

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A. Appendix

In this section, we provide proofs of the propositions.

A.1 Proof of Proposition 1

For proof of this proposition, first observe that (15) implies that $H' > 0$ for any e_t, $H'' > 0$ for $e_t < \bar{e}$ and $H'' = 0$ for $e_t \geq \bar{e}$. Thus, the law of motion is convex for $e_t < \bar{e}$ and then linear thereafter. Also, it is continuous for all e_t. To see this, H is piece-wise continuous for $e < \bar{e}$ and $e \geq \bar{e}$ and, $\lim_{e \to \bar{e}^-} H(e) = \lim_{e \to \bar{e}^+} H(e)$.

*Existence: Graphically, the fixed points exist where the graph crosses the 45 degree line. Since $H(0) = 0$, the existence of the poverty trap fixed point e^{φ} is guaranteed. Moreover, there may exist at most one more fixed point, $e^u > 0$ if and only if the long-run growth rate along the sustained growth path satisfies $g = \xi \frac{\theta\psi^{\varepsilon+\nu}\bar{e}^{\varepsilon}}{1+\theta\psi^{\varepsilon}\bar{e}^{\varepsilon}} > 1$. To see this, suppose $g > 1$, then $H(e_t) = e_{t+1} \geq e_t$, for any $e_t \geq \bar{e}$. By $H(0) = 0$ and the continuity of H, its graph crosses the 45 degree line for some $e_t < \bar{e}$. Conversely, suppose that the graph is above the 45 degree line at $\bar{e}$ but $g < 1$,then $H(e_t) < \bar{e}$ too. This is contradictory. Suppose even if e^u exists, it is not along the convex part of the graph. So the fixed point is made at the linear part, where $e_t > \bar{e}$. This means that $\lim_{e \to \bar{e}^-} H'(e) = (1 + \varepsilon\kappa)g < 1$, but $\lim_{e \to \bar{e}^+} H'(e) = g > 1$, where $\kappa = \frac{1}{(1+\theta\psi^{\varepsilon}\bar{e}^{\varepsilon})}$. Since $\kappa \in (0, 1)$, this is contradiction.[12] This implies that e^u exists along the convex part as in Figure 2. Therefore, H crosses the 45 degree line just once for $e > 0$. Clearly, e^{φ} is stable and e^u is unstable.

A.2 Proof of Proposition 2

From eq (15), $\frac{\partial H(e_t)}{\partial \theta} > 0$. Since $\frac{\partial \theta}{\partial q} > 0$ (recall $\theta \equiv A(1 + \alpha q)$), the first result follows immediately. Recall e^u is the positive fixed point at which $H(e^u) = e^u$. Since an increase in q shifts up $H(e)$, it moves the fixed point to the left. From Proposition (1B) the long-run growth rate is $g = \xi \frac{\theta\psi^{\varepsilon+\nu}\bar{e}^{\varepsilon}}{1+\theta\psi^{\varepsilon}\bar{e}^{\varepsilon}}$. The result obtains because $\frac{\partial g}{\partial q} = \frac{\partial g}{\partial \theta}\frac{\partial \theta}{\partial q} > 0$

B. Data Appendix on construction of additional variables used in analysis

B.1 Inequality

Gini coefficient, Logarithmic Variance and Variance of logarithms of consumer expenditure data were computed at individual level using price-deflated measures of expenditure. We referred to 42nd, 43rd and 50th NSS Survey Rounds to compute inequality for every state-region.

$$Logarithmic\ Variance \ = \frac{1}{n}\sum_i [log\left(\frac{y_i}{\bar{y}}\right)]^2$$

$$Variance\ of\ logarithms \ = \frac{1}{n}\sum_i [log\left(\frac{y_i}{y^*}\right)]^2$$

where $\bar{y}$ is the mean of y_i (income) and y^* is the geometric mean of y_i. We note that while the logarithmic variance is a commonly used measure of inequality, the variance of logarithms has also been used as an alternative (Cowell 2011). Since income data is unavailable in the NSSO, we use per capita monthly consumption expenditure data to compute our inequality measures.

[12] The discussion indicates that there may exists infinite fixed points in a special case when $g = 1$. This case is rather non-generic and not interesting in terms of economic dynamics we aim to analyze. Also, this has a counter-factual economic implication that the sustained growth occurs only when the observed longevity reaches the biological limit. Thus, we do not consider it.

B.2 Per capita number of community health centers (CHC)

This serves as a proxy for the supply of public health care. It measures the number of Community Health Centres reported during the Five year plan (1981-85), at the state level. We use the state level population data from 1981 census to compute the per capita number of CHCs in a state. This data is from Rural Health Statistics Report (2014-15)[13], and the population data is from the Planning Commission Report. For the newly formed states, such as, Chhattisgarh, Jharkhand, Telengana or Uttarakhand, we use the same population numbers as the corresponding original state (from which these new states were formed).

B.3 Non-Vaccine indicators

We used other proxy variables to understand the relative private to public mix in health care delivery. For this we used the questions asked during 42nd NSS Round, whereby the respondents had to indicate whether they received the care form private or public sources. The questions asked were: (a) Whether the child was hospitalised on account of any ailment/injury during the last 365 days, (b) Whether the mother was registered for prenatal care in hospital or with doctor, (c) Whether the mother was registered for post-natal care in hospital or PHC.

The common options stated for these questions were: NA; Public Hospital; Primary Health Centre; Public Dispensary; Private Hospital; Nursing Home; Charitable institution run by trust; government doctor; private doctor; Others. Any individual who received health care from a public hospital or a primary health centre or a public dispensary or a government doctor was categorized as having received health care form public sources. Everyone else was categorized to have received it from private sources. This individual data was then aggregated to regional level.

B.4 Disability due to Polio

This was derived at the individual level form the 58th Round (2002), Schedule 26 of the Survey of Disabled Persons. The specific question was whether the individual reported any disability; if so whether this was form birth and if not, then what is the cause of the disability. Individuals who reported disability due to Polio were assigned a unit value and the others assumed a value zero for this binary indicator variable.

[13] Source: http://wcd.nic.in/sites/default/files/RHS_1.pdf

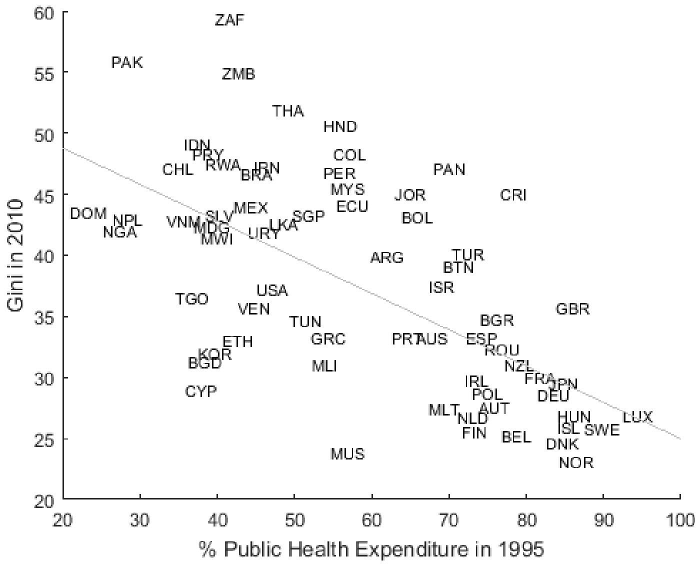
Preference against Public health due to quality issue: This was computed at the individual level from the 60th NSS Round (2004), Schedule 25. This question was asked to individuals who reported any ailment during the last 15 days. The specific question was whether any treatment was taken on medical advice; if yes, then whether any treatment received from government sources. If the treatment was not sought from the government sources, individuals were asked to list reasons for overlooking public facilities. The choices were: (a) government doctor/facility too far; (b) not satisfied with medical treatment by government doctor/facility; (c) Long waiting period before one can get appointment; (d) required specific services not available; and (e) others. We generated a binary indicator variable equal to 1 when individuals reported that they did not seek the government advice as they were not satisfied with the quality. The others were assigned a zero value. The variable proxies for strong preferences against using the public health facilities.

B.5 Imputed total Health Expenditure (% Gross State Domestic Product (GSDP))

Total health expenditure has public and private components. We obtain state level data on Public health expenditure (as % Gross State Domestic Product) from the Health Care Expenditure statistics from the Government of India for the period 1974-75 to 1990-99, published by the National Institute of Public Finance and Policy.[14] We use the public share data as of 1986-87 (at current Prices). As private health expenditure data is unavailable, we use an approximate ratio of Public to Private Hospitals, from Special Statistics on Health Expenditure across States by Centre for Enquiry into Health and Allied Themes (CEHAT). As the ratio is stated as 45.3 to 54.7, we use it to compute the private health expenditure (as % Gross state Domestic Product). Finally, we add up the two components to derive the share of total health expenditure (%GSDP).

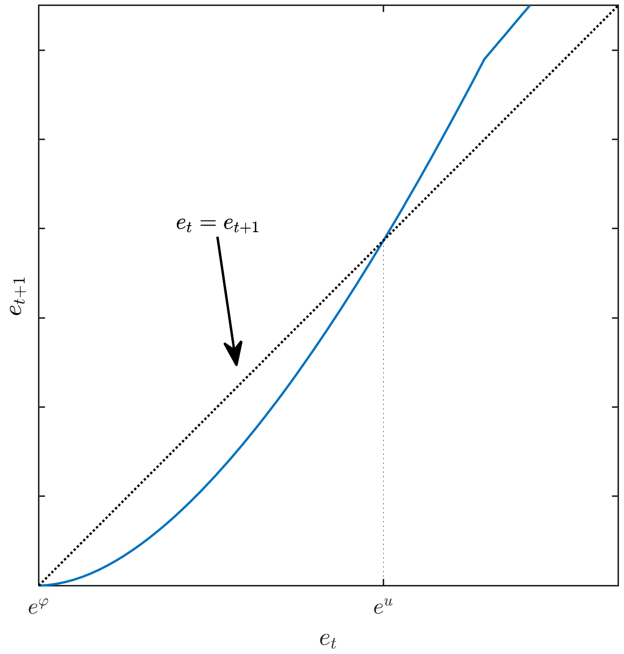
[14] See: http://www.nipfp.org.in/media/medialibrary/2014/10/HEALTH_CARE_EXPENDITURE_BY_GOVERNMENT_IN_INDIA_1947-75_TO_1990-91.pdf.

Figure 1: Long-run effect of health care system on income inequality



Source: The World Bank Database; The Standardised World Income Inequality database (SWIID database)
Notes: The horizontal axis represents the public health expenditure as percentage of total health expenditure as of 1995, which proxies the extent to which a country is leaning toward the public healthcare regime. The vertical axis is the Gini coefficient in 2010 based on disposable income.
ISO 3166-1 alpha-3 nomenclature is used for the country codes.

Figure 2: Earnings dynamics under homogeneous households
Fixed point equilibria



B. Earnings dynamics under different mix of private and public health expenditure

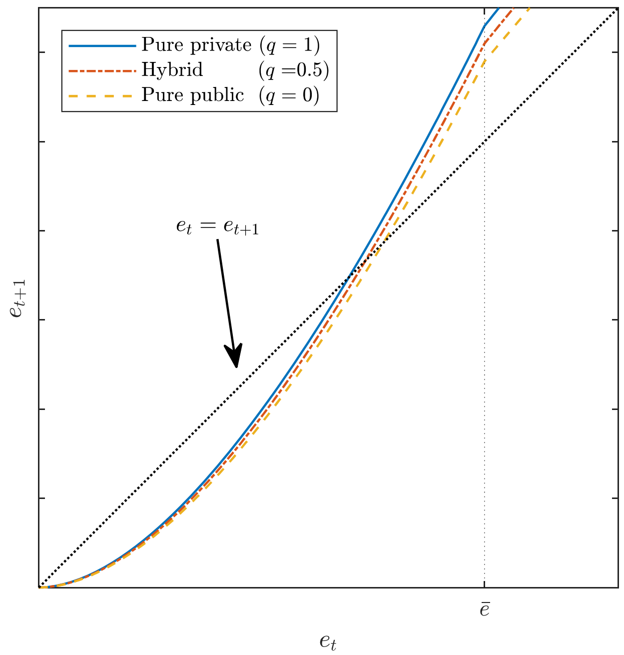


Figure 3: Dynamics of Gini coefficients under different private-public mix of health expenditure

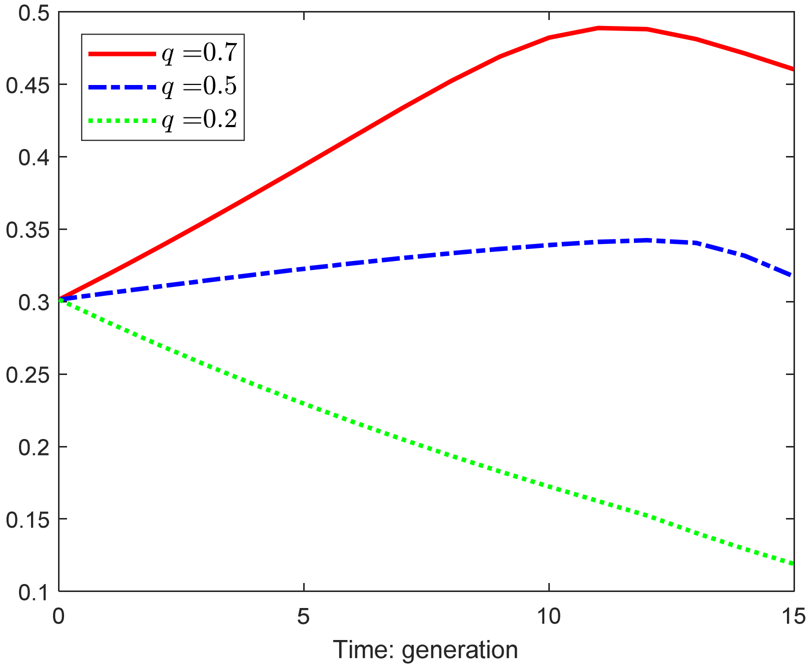
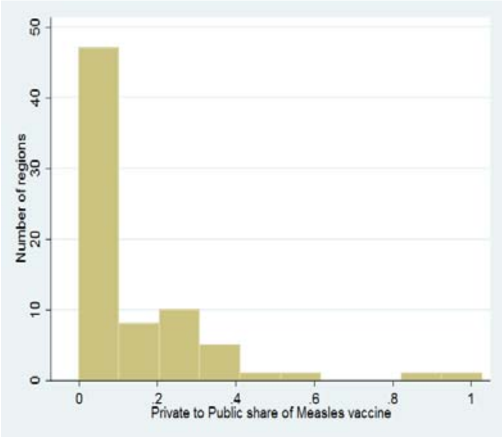
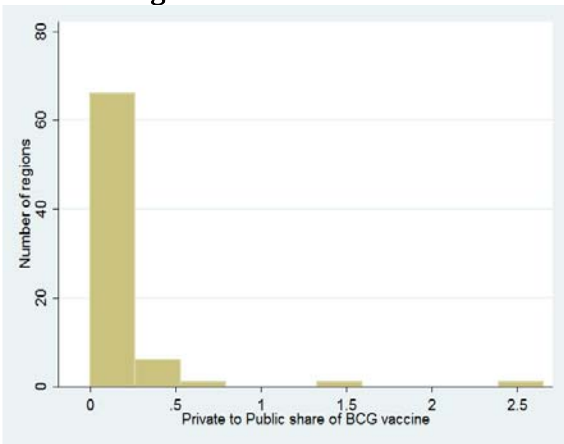


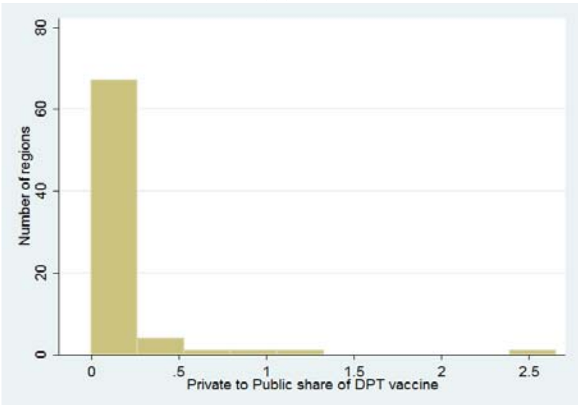
Figure 4: Relative distribution of private and public providers of Measles, BCG, DPT and Polio vaccines during 1986-87



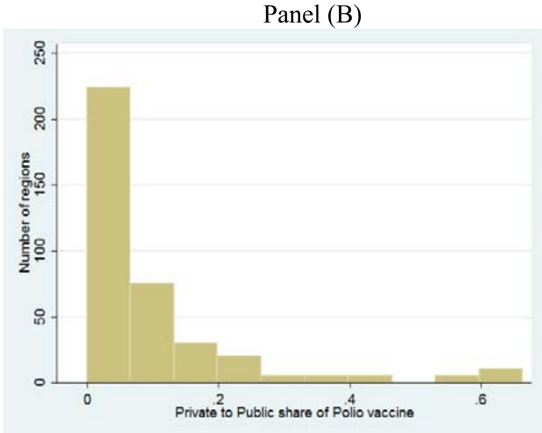
Panel (A)



Panel (B)



Panel (C)

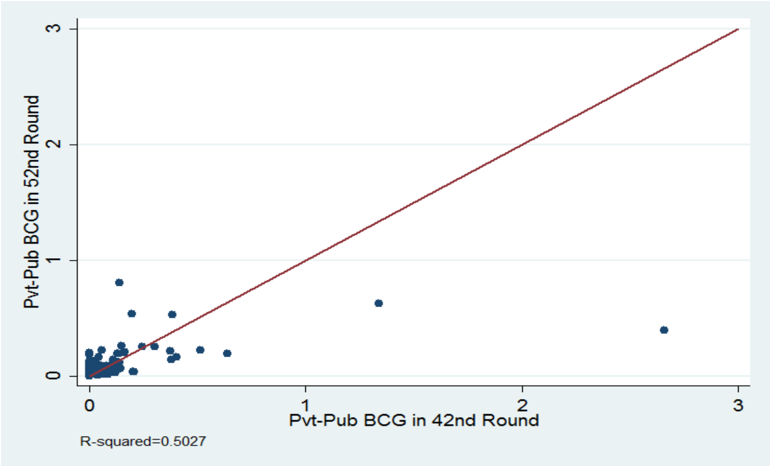


Panel (D)

Source: Aggregated at the regional level using data from the 42nd NSS Round.

Notes: The horizontal axis represents the measure of relative share of private to public sources for different vaccines of our study. The relative share of the vaccine providers is given by the ratio of the proportion of individuals, out of the total valid entries, who received the vaccine from private to the proportion of individuals, out of the total valid entries, who received it from public sources in a region. Relative share of private and public sources vary across vaccines. While Measles vaccine in several regions is provided by both public and priavte providers, there is a clear dominance of public providers in the case of DPT vaccine.

Figure 5: Relative share of Private to public providers of BCG vaccine in 42nd and 52nd NSS Rounds



Notes: The horizontal axis depicts the relative share of private to public providers of BCG vaccines in 42nd NSS Round (1986-87). The vertical axis represents the same during the 52nd NSS Round (1995-96). Clustering of the points near the 45 degree line denotes that the regional pattern of the share of private to public provisioning did not change across the two survey rounds. From this, we can identify only two regions where the patterns differed over time. We treat them as potential outliers. These two regions are "Central Bihar" and "Himalayan West Bengal".

Table 1: Baseline calibration

Parameter	Description	Calibrated value	Matching
q	Share of private expenditure in total health expenditure	0.7	Indian sample, 1995-2014
A	Effectiveness (scale) parameter of health expenditure	0.2866	Life expectancy, India 1985-2015
ϵ	Elasticity of longevity increase with respect to health input	0.21	Life expectancy, India 1985-2015
α	Share of total (public + private) expenditure to consumption	0.05	Indian sample, 1995-2014
ν	Effect of childhood health investment on human capital production	0.1	Dottori (2009). Also, Bloom, Canning, and Sevilla (2004) and WHO, World Health Organization (2001)
ξ	Scale parameter for human capital production	4.1548	Long-run annual growth of 2%

Sources: Indian data are obtained through World Bank Open Data.

Table 2: Summary statistics of variables used in analysis

	Mean	Standard deviation
Measles	0.131	0.192
DPT	0.143	0.359
BCG	0.147	0.351
Polio	0.093	0.136
Where was child hospitalised for ailment	0.848	1.455
Where mother registered for prenatal care	0.812	1.204
Where mother registered for postnatal care	0.839	1.225
Per capita total CHCs	0.017	0.029
Imputed total Health Expenditure (%GSDP)	4.021	3.511
Initial Inequality (Gini from 42nd NSS Survey)	0.814	0.022
Sample Size (N= 76)		
Section B		
Gini coefficient	0.533	0.071
Logarithm of variance	1.378	0.379
Variance of Logarithm	1.020	0.259
% population with secondary education	8.345	3.913
% Hindu population	77.953	23.769
% rural population	73.528	16.621
% scheduled caste (SC)	16.559	8.917
Sample Size (N= 379)		
Section C		
Disability due to Polio	0.099	0.299
Sample Size (N= 78,827)		
Preference against public health facilities due to poor perceived quality	0.348	0.476
Sample Size (N= 29,516)		

Notes: Section A - Each vaccine (measles, DPT, BCG and Polio) represents the relative share of private to public sources of vaccines in each region from the 42nd NSS round (1986-87). There are 76 observations corresponding to 76 regions.

Table 3: Pooled OLS estimates of the effect of relative private to public investments on income inequality [Robust standard error]

	Gini Coefficient			*Logarithm of Variance*		
	Unadjusted for control variables	Adjusted for control variables [m]	Adjusted for control variables &a non-vaccine private-public mix)	Unadjusted for control variables	Adjusted for control variables [m]	Adjusted for control variables & a non-vaccine private-public mix
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
Panel A.						
Measles	0.041**	0.041**	0.035*	0.187*	0.175**	0.174**
	[0.021]	[0.017]	[0.018]	[0.098]	[0.079]	[0.084]
Place of child hospitalisation			0.004 [0.003]			0.003 [0.010]
Year effect	Y	Y	Y	Y	Y	Y
R-squared	0.047	0.140	0.170	0.237	0.364	0.399
Sample Size	369	366	351	369	366	351
Panel B. Only using non-vaccine private to public mix:						
Place of child hospitalisation	0.005** [0.002]	0.005* [0.003]	-	0.016 [0.01]	0.009 [0.009]	-
Place of prenatal care	0.007*** [0.003]	0.006** [0.002]	-	0.035*** [0.012]	0.030*** [0.011]	-
Place of postnatal care	0.006** [0.003]	0.005* [0.003]	-	0.033** [0.013]	0.014 [0.014]	-

Notes: Outcome variable is the Gini coefficient and the logarithm variance of per capita consumption expenditure at regional levels. Regressions are pooled ordinary least squares (OLS). Columns (1a) and (2a) are without any control variables. In columns (1b) and (2b) we control for the following control variables [m] rural population, education, social group, religion at the regional level, initial inequality from the 42nd round, per-capita number of community health centers (CHCs), and share of total health expenditure in the Gross State Domestic Product (GDSP), imputed with the average across states for the missing observations and year effects. Columns (1c) and (2c) control for a non-vaccine private-public health mix, in addition to the control variables used in Columns (1b) and (2b). The number of CHCs, the expenditure data and non-vaccine measures approximately correspond to our base year of analysis, 1986-87. Standard errors are corrected for heteroscedasticity and clustered at region level.

**** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.*

Table 4: Instrumental variable estimates of the effect of relative private to public investments in vaccines on income inequality [robust standard error]

	Gini Coefficient			*Logarithm of Variance*			*Variance of logarithms*	
	Unadjusted for control variables	Adjusted for control variables	Adjusted for control variables, initial inequality, per capita CHCs and total health expenditure(%GSDP)	Unadjusted for control variables	Adjusted for control variables	Adjusted for control variables, initial inequality, per capita CHCs and total health expenditure(%GSDP)	Unadjusted for control variables	Adjusted for control variables, initial inequality, per capita CHCs and total health expenditure(%GSDP)
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3c)
A. Measles	0.057**	0.055**	0.061**	0.324***	0.281**	0.243**	0.258***	0.202**
	[0.024]	[0.022]	[0.025]	[0.122]	[0.111]	[0.119]	[0.094]	[0.088]
B. DPT	0.052**	0.050**	0.053**	0.279**	0.250**	0.241*	0.224**	0.177**
	[0.023]	[0.023]	[0.023]	[0.114]	[0.113]	[0.130]	[0.089]	[0.085]
C. BCG	0.086**	0.083**	0.089**	0.504***	0.439**	0.377**	0.400***	0.314**
	[0.034]	[0.033]	[0.036]	[0.177]	[0.172]	[0.184]	[0.135]	[0.135]
Year effect	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Outcome variable is the Gini coefficient and the logarithm variance of per capita consumption expenditure at regional level. Columns (1a), (2a) and (3a) are without control variables. Control variables in columns (1b) and (2b) include the Share of rural population, Percentage of population with secondary education, social group and religion at the regional level. Columns (1c), (2c) and (3c) adjust for regional inequality measures from the 42nd Round, state level per capita CHCs and total health expenditure (% GSDP) at state level, in addition to the control variables used in Columns (1b) and (2b). Both the number of CHCs and the expenditure data approximately correspond to the base line year, 1986-87. The excluded instrumental variable in each case is the private to public ratio of the source of polio vaccine at regional level. First Stage F-statistic for Measles is 32.35; for DPT is 25.42; for BCG is 10.73. Standard errors are corrected for heteroscedasticity and clustered at region level.

**** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.*

Table 5: Stability in regression coefficients over time [standard error]

	2011-12 (1)	2009-10, 2011-12 (2)	2004-05, 2009-10, 2011-12 (3)	1993-94, 2004-05, 2009-10, 2011-12 (4)
Pooled OLS				
Log Variance				
Measles	0.121	0.175**	0.152**	0.148**
	[0.127]	[0.077]	[0.069]	[0.070]
Sample Size	74	148	221	293
Variance of Logarithms				
Measles	0.088	0.121**	0.111**	0.111**
	[0.079]	[0.052]	[0.047]	[0.048]
Sample Size	74	148	221	293
Gini				
Measles	-0.004	0.031	0.035*	0.035**
	[0.035]	[0.021]	[0.019]	[0.017]
Sample Size	74	148	221	293
Instrumental variable analysis				
Logarithmic Variance				
Measles	0.203	0.292**	0.260**	0.245**
	[0.188]	[0.130]	[0.117]	[0.111]
DPT	0.190	0.255**	0.225**	0.221*
	[0.177]	[0.119]	[0.110]	[0.112]
BCG	0.301	0.415**	0.368*	0.345*
	[0.276]	[0.206]	[0.188]	[0.187]

Notes: The unit of observation is region-year. Outcome variable is the Gini coefficient and the logarithm variance of per capita consumption expenditure at regional level. The five survey rounds considered for analysis are- 43rd round (1987-1988) 50th round, (1993-1994); 61st round, (2004-2005); 66th round, (2009-2010) and 68th round, (2011-2012). Column (1) uses the latest Consumer Expenditure NSS Survey (68th) and the relative private to public vaccine sources from the 42nd NSS Round; Column (2) uses the latest two Consumer Expenditure NSS Surveys (68th & 66th); Column (3) uses the latest three Consumer Expenditure NSS Surveys (68th, 66th and 61st); Column (4) uses the latest four Consumer Expenditure NSS Surveys (68th, 66th, 61st and 50th). The control variables used in all the columns include the Share of rural population, Percentage of population with secondary education, social group, religion and year effects. The excluded instrumental variable is the private to public ratio of the source of polio vaccine at regional level. Standard errors are corrected for heteroscedasticity and clustered at region level.

**** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.*

Table 6: Relationship between preferences for public health facilities and income inequality [robust standard error]

	Preference against using public health facility as the service quality is not satisfactory (2004)	
	Unadjusted (1)	Adjusted for control variables (2)
Inequality in 1987-88 (43rd Round)		
Gini	-0.195	-0.134
	[0.332]	[0.334]
Logarithm of variance	-0.008	-0.014
	[0.056]	[0.057]
Sample size	29,513	29,341
Inequality in 1993-94 (50th Round)		
Gini	-0.221	-0.143
	[0.406]	[0.398]
Logarithm of variance	0.005	0.002
	[0.074]	[0.075]
Sample size	29,323	29,151

Notes: This table reports Pooled OLS results. Dependent variable is a binary variable equal to 1 if individuals preferred not to use the government sources for treatment because they were not satisfied with the quality. All other individuals who opted for public or private sources of treatment for other reasons assumed an indicator value, zero. Data on preference comes from the 60th NSSO Survey on Morbidity & Health care (2004). The inequality measure is at regional level from the 43rd NSS Survey (1987-88). We also separately use inequality measures from the 50th NSS Survey (1993-94). Control variables include age, sector and social group of the individuals. Standard errors are corrected for heteroscedasticity and clustered at region level.
**** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.*

Table 7: Relationship between ratio of private-public investments in polio vaccine on subsequent disability due to Polio [robust standard error]

Cause of disability due to Polio (2002)		
	Polio as the cause of disability (unadjusted)	Polio as the cause of disability (adjusted)
	(1)	(2)
Private-public polio vaccine in 1986-87	-0.023	-0.022
	[0.025]	[0.024]
Sample size	78,827	78,709

Notes: This table reports Pooled OLS results. Dependent variable is a binary variable equal to 1 if an individual reports disability due to Polio. All other individuals, reporting disability due to other reasons assume a value zero. Data on disability comes from the 58th NSSO Survey of Disabled Persons (2002). Private-public sources of the polio vaccine is at region level, from the 42nd NSS Round. Column (1) is without any control variable. Column (2) controls for sector, Class according to expenditure level, social group, general education of the principal earner in the household. Standard errors are corrected for heteroscedasticity and clustered at the region level.
**** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.*